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(71) Applicant *(for all designated States except US)*: HORSTMANN TIMERS & CONTROLS LIMITED [GB/GB]; Newbridge Road, Bath BA1 3EF (GB).

(71)(72) Applicant and Inventor: TRONTELJ, Janez [SI/SI]; University of Ljubljana, Trzaska 25, 61111 Ljubljana (SI).

(74) Agent: SARUP, David, Alexander; Withers & Rogers, 4 Dyer's Buildings, Holborn, London EC1N 2JT (GB).

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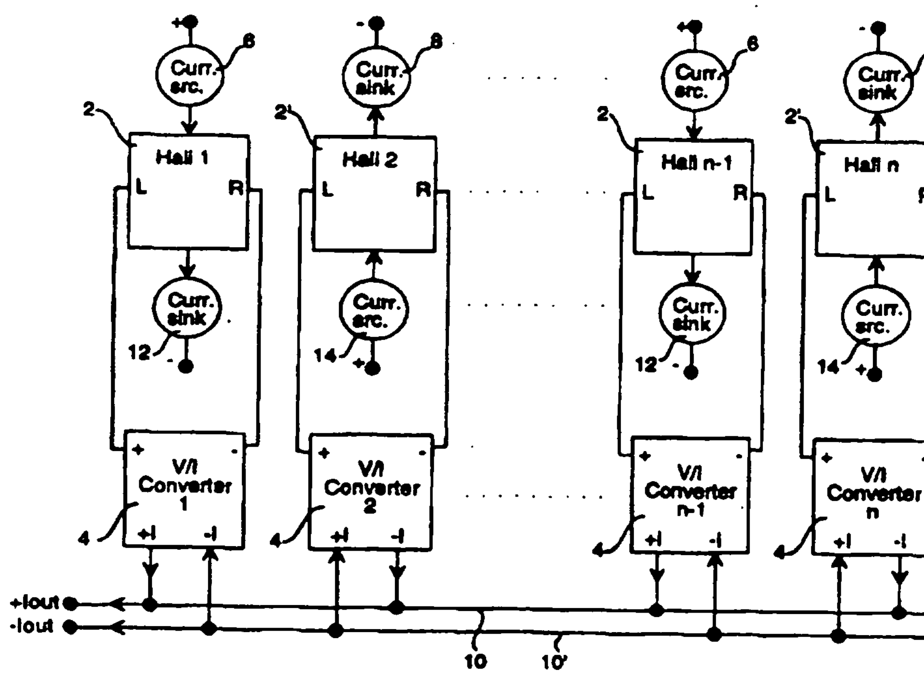

(57) Abstract

An electricity meter includes two sensors which detect electromagnetic field induced by a conductor and each sensor provides a current signal dependent on the magnitude of the detected field. The two current signals are combined by differencing so as to remove error components due to D.C. offsets.

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ELECTRICITY MEASUREMENT APPARATUS

The present invention relates to an electricity measurement apparatus and a method of electricity measurement, in particular for current measurement, power measurement and Watthour metering.

When current flows through a conductor, a rotational magnetic field is set up. The magnitude of this magnetic field is proportional to the density of current flowing:

$$B \propto I/A \qquad \text{(Equation 1)}$$

where I is the total current, and A is the cross sectional area of the conductor. This value I/A is the current density J.

It is known to use sensors, such as Hall effect sensors, to measure current flow though a conductor by detecting the magnetic field. For example, using a Hall effect sensor, the sensor output signal has a voltage, VH, which is proportional to the magnetic field strength B at the sensor, and a reference current Iref flowing through the sensor as follows:

$$VH = S \times B \times Iref \qquad \text{(Equation 2).}$$

The proportionality coefficient S is the sensitivity of the sensor. By keeping constant the current through the Hall sensor, a linear relationship is achieved between the detected

magnetic field and output voltage.

If such a sensor is placed near a conductor, the two equations (1) and (2) above can be combined allowing current flow J to be determined, current flow J being proportional to Hall voltage VH.

The present invention is defined in the claims to which reference should now be made. Preferred features are laid-out in the sub claims.

The present invention preferably provides electricity measurement apparatus operative to measure current flow along a conductor, the apparatus including a first sensor and a second sensor, each sensor being operative to detect magnetic field and to provide a current signal dependent thereon at an output port, the output ports of the first and second sensors being connected together so as to provide a combined current signal of the difference between the current signals from the sensors, a systematic error in the combined signal being smaller in magnitude than systematic error components in the current signals from the sensors. Preferably, the systematic error components in the signals from the sensors are substantially cancelled by the differencing.

The two sensors are preferably disposed equidistant from an magnetic field inducing conductor such that the sensors experience equal magnitude fields. The conductor can be a mains electricity supply conductor, in particular conducting A.C. electricity of an electrical supply network. Alternatively the conductor can conduct D.C. electricity. The sensors can be on the same side of the conductor, or on opposite sides such that the impinging field is

of the same magnitude but opposite polarity. There can be multiple pairs of sensors.

The sensors are preferably Hall sensors. sensors of a pair preferably being supplied with supply currents in opposite directions. Sensors are preferably connected via voltage to current convertors such that alternate positive and negative output terminals of the convertors are connected to a common line to provide the combined current signal. This has the advantage that differential voltage amplifiers, which would themselves give rise to errors, are not required to do the differencing operation.

A preferred embodiment of the present invention will now be described. by way of example. and with reference to the figures. in which:

Figure 1 is a circuit diagram of a preferred embodiment of the invention; and

Figure 2 is a simplified schematic of the circuit.

As shown in Figure 1, the circuit consists of multiple pairs of Hall sensors 2,2'. each having left L and right R terminals connected to terminals of voltage-to-current convertor 4. Each Hall sensor 2,2' receives a supply current from a current source 6,14 which passes via a Hall sensor 2,2' to a current sink 12,8. Each of a pair of Hall sensors 2,2' has current supplied in opposite directions.

The two Hall sensors 2,2' of a pair are equidistant from a mains conductor which transmits A.C. electricity and which induces an electromagnetic field around itself as mains current

flows such that the sensors 2,2' experience the same magnitude of electromagnetic field. In alternative embodiments D.C. electricity could be conducted by the conductor. All sensors are constructed on a single integrated circuit and so can be assumed to have common D.C. offset errors and sensitivities to applied electromagnetic fields.

Each Hall sensor 2,2' has a potential difference VH' across it between left L and right R terminals dependent on the magnitude of an electromagnetic field detected by that sensor 2,2'.

The voltage signals from left L and right R terminals are supplied to the voltage-to-current convertor 4 which provides a current value IH' proportional to the potential difference VH'.

Irrespective of the direction of supply current, Hall sensors have D.C. offset errors which can change due to age, temperature and other factors. For multiple Hall sensors manufactured on a single integrated circuit as in the present embodiment, these errors can be assumed to be equal.

Odd sensors will provide voltage signals VH' as:

$$VH' = VH + VE \qquad \text{(Equation 3)}$$

where VH' is a measured potential difference, VH is the true Hall voltage, VE is a D.C. offset error. Conversely, even sensors provide voltage signals VH' as:

$$VH' = -VH + VE \qquad \text{(Equation 4)}$$

After conversion into currents, the following relations apply:

for odd sensors:

$$IH' = IH + IE \qquad \text{(Equation 5)}$$

for even sensors:

$$IH' = -IH + IE \qquad \text{(Equation 6)}$$

where IH' is the output current signal from a Hall sensor.

Combining the output current signal from a first and second sensor and assuming that both sensors have the same D.C. offset error IE give:

$$IH_1' - IH_2' = IH_1 + IE - (-IH_2 + IE) \qquad = IH_1 + IH_2$$

(Equation 7).

Assuming $IH_1 = IH_2 = IH$ ie that both sensors experience the same magnitude of magnetic field and have the same sensitivity, gives:

$$IH_1' - IH_2' = 2IH \qquad \text{(Equation 8).}$$

Including components for each of the further sensor pairs gives:

$$I_{OUT} = \sum_{m=1}^{n/2} (IH_{2m-1}' - IH_{2m}') = 2m\,(IH) = n(IH) \qquad \text{(Equation 9)}$$

where n is the number of sensors (an even number 2, 4, 6 .....).

It can be seen that D.C. error components are simply removed by differencing.

Conversion to current allows this differencing to occur in a very simple manner as illustrated schematically in Figure 2. Simply by connecting alternate positive and negative output terminals of voltage to current convertors 4 to a common line 10,10' the current along the common line is:

$$I_{OUT} = IH + IE + IH_2 - IE + IH_3 + IE + IH_4 - IE \qquad \text{(Equation 10)}$$

$I_{OUT} = n\,(IH)$ where n is the number of sensors.

CLAIMS

1. Electricity measurement apparatus operative to measure electricity flow along a conductor. the apparatus including a first sensor and a second sensor. each sensor being operative to detect electromagnetic field induced by the conductor and to provide a current signal dependent thereon at an output port. the output ports of the first and second sensors being connected together so as to provide a combined current signal of the difference between the current signals from the sensors. a systematic error in the combined signal being smaller in magnitude than systematic error components in the current signals from the sensors.

2. Electricity measurement apparatus according to claim 1, in which the systematic error components in the signals from the sensors are substantially cancelled by the differencing.

3. Electricity measurement apparatus according to claim 1 or claim 2. in which the two sensors are disposed equidistant from the electromagnetic field inducing conductor such that the sensors experience at least substantially equal magnitude fields.

4. Electricity measurement apparatus according to any preceding claim. in which the conductor is a electricity mains supply conductor.

5. Electricity measurement apparatus according to claim 4, in which the conductor conducts A.C. electricity.

6. Electricity measurement apparatus according to any preceding claim. in which the sensors are on the same side of the conductor.

7. Electricity measurement apparatus according to any of claims 1 to 5. in which the. sensors are on opposite sides such that the respective impinging magnetic fields are of substantially the same magnitude but opposite polarity.

8. Electricity measurement apparatus according to any preceding claim in which there are multiple pairs of sensors. each pair comprising one first sensor and one second sensor.

9. Electricity measurement apparatus according to claim 8. in which the sensors of a pair are supplied with supply currents in opposite directions.

10. Electricity measurement apparatus according to any preceding claim. in which the magnetic field sensors are Hall-effect sensors.

11. Electricity measurement apparatus according to any preceding claim. in which sensors are each connected to a respective voltage to current converter. the output terminals of which are connected to a common line to provide the combined current signal such that the positive output terminal of each convertor connected to a first sensor and the negative output terminal of each converter connected to a second sensor are connected to the common line.

12. Electricity measurement apparatus according to any preceding claim. in which sensors are each connected to a respective voltage to current converter. the output terminals of which are connected to common lines to provide the combined current signals such that the positive output terminal of each convertor connected to a first sensor and the negative output terminal of each converter connected to a second sensor are connected to a first common line. and the

negative output terminal of each convertor connected to a first sensor and the positive output terminal of each convertor connected to a sensor are connected to a second common line, the combined current signal being provided on both lines.

13. Electricity measurement apparatus according to any preceding claim in which the systematic error components are D.C. offset errors.

14. Electricity measurement apparatus according to any preceding claim for current measurement, power measurement and/or watt hour determination.

15. A method of measuring electricity flow along a conductor using a first magnetic field sensor and a second magnetic field sensor, each sensor providing a current signal dependent upon detected magnetic field and including a systematic error component, the current signals being combined by differencing such that the systematic error in the combined signal is smaller in magnitude than the systematic error components.

16. A method of measuring electricity flow along a conductor according to claim 15, in which the systematic error is a D.C. offset error.

17. A method of measuring electricity flow according to claim 15 or claim 16, in which the sensors are Hall sensors.

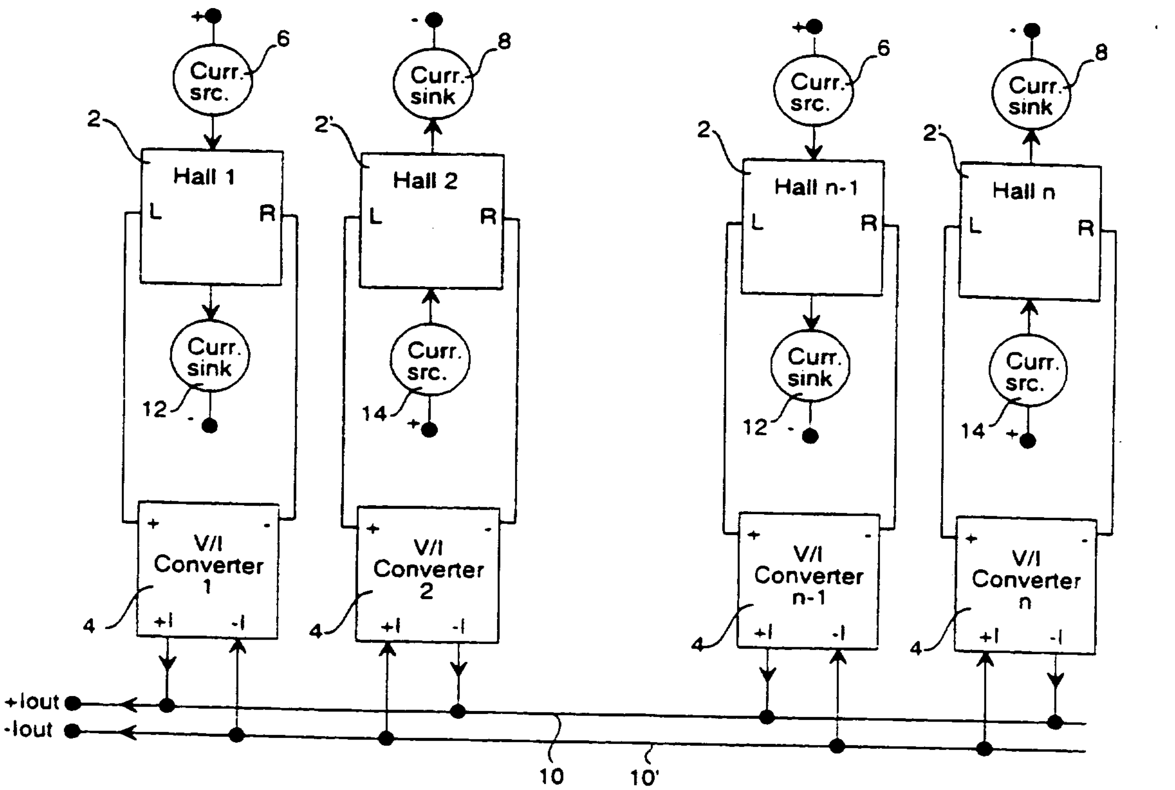

Figure 1

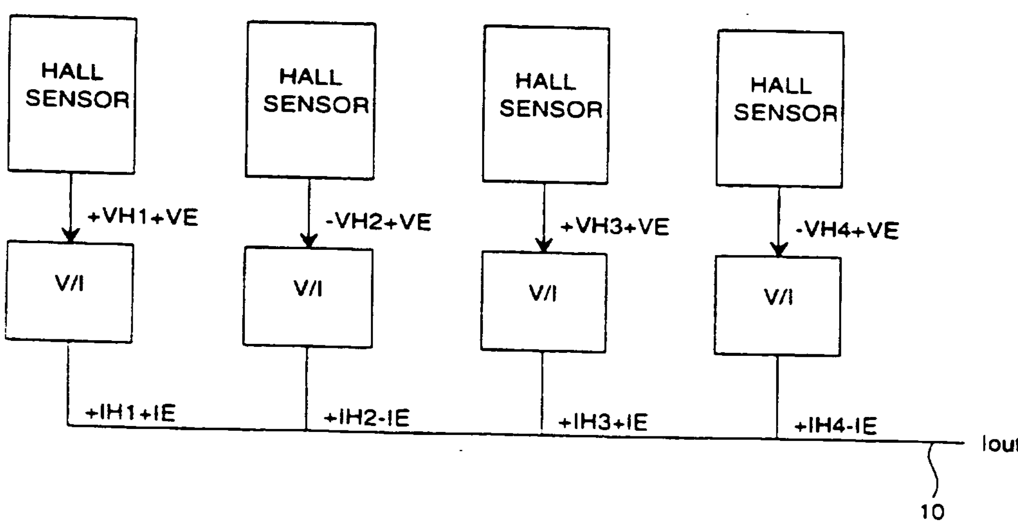

Figure 2

INTERNATIONAL SEARCH REPORT

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A. CLASSIFICATION OF SUBJECT MATTER
IPC 6 G01R15/20

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 6 G01R

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US,A,5 017 804 (HARNDEN) 21 May 1991 see column 2, line 53 - column 4, line 39 ---	1-4,7, 10,13, 15-17
X	PATENT ABSTRACTS OF JAPAN vol. 6, no. 225 (P-154) [1103] , 10 October 1982 & JP,A,57 128854 (MITSUBISHI) see abstract ---	1-4, 14-17
X	PATENT ABSTRACTS OF JAPAN vol. 8, no. 92 (P-271) [1529] , 27 April 1984 & JP,A,59 007269 (FUJI) see abstract --- -/--	1-4

[X] Further documents are listed in the continuation of box C.

[X] Patent family members are listed in annex.

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Date of the actual completion of the international search	Date of mailing of the international search report
6 June 1996	18.07.96

Name and mailing address of the ISA	Authorized officer
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C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	NTIS TECH NOTES, vol. 1, no. 1, April 1990, SPRINGFIELD,VA,US, page 329 XP000127997 "hall-effect current sensors" see page 329	1-4

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Information on patent family members

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Patent document cited in search report	Publication date	Patent family member(s)	Publication date
US-A-5017804	21-05-91	NONE	

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